ScECAL Beam Test @ FNAL in '08 & '09
– Analysis Status –

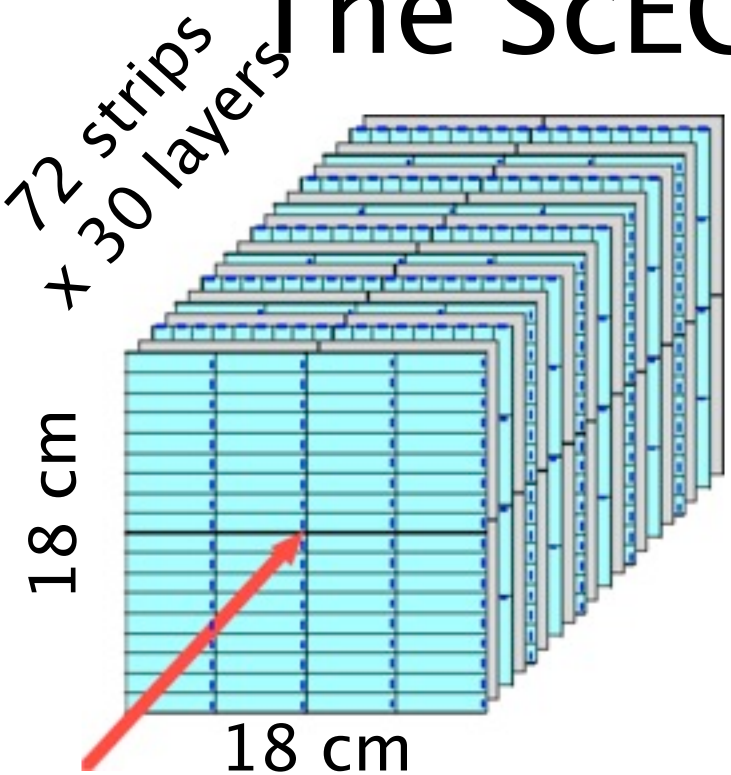
Sep 2012 CALICE week @ Cambridge

Satoru Uozumi for CALICE-ASIA

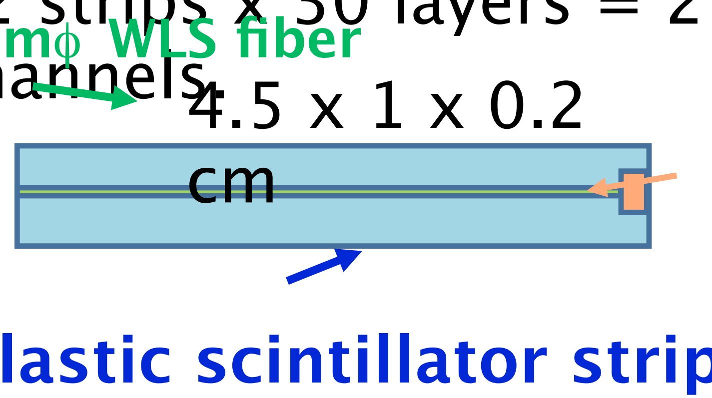
– Contents –

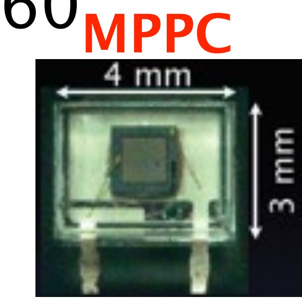
- Results @ previous CALICE week
- Preliminary estimate of systematic uncertainties
- 2nd-order temperature correction
- Estimation of EM shower leak by Mokka
- Effect of beam momentum spread
- Summary & plan

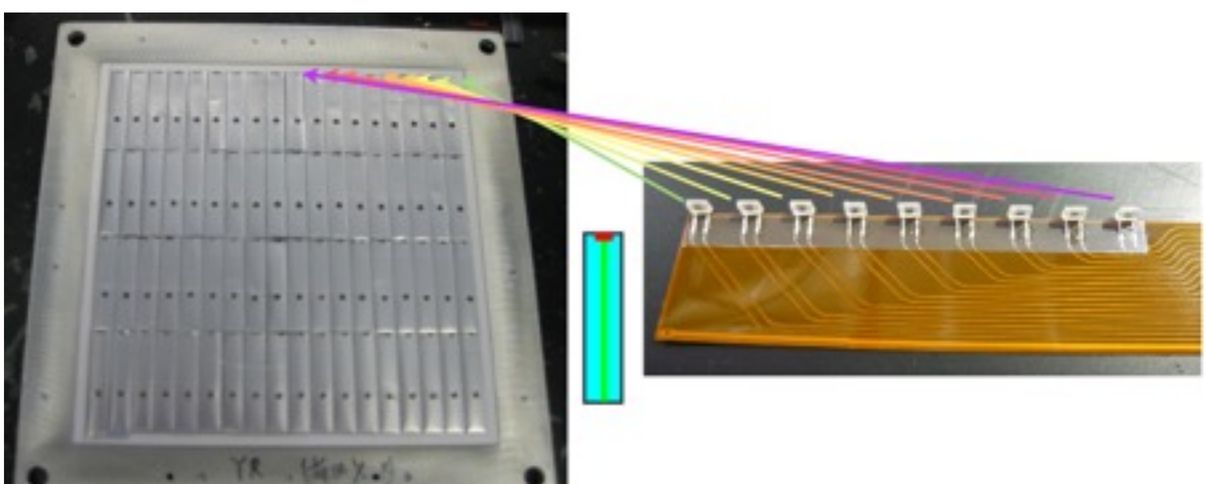
The ScECAL 2nd Prototype

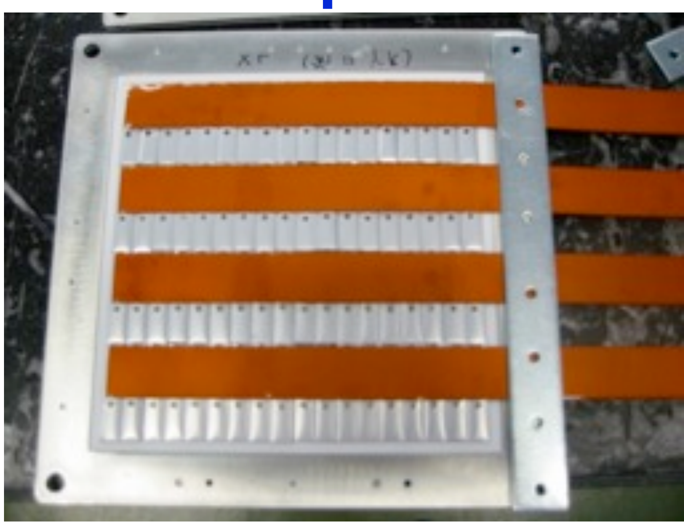


- The technical prototype to establish the ScECAL feasibility.
- Strips are orthogonal in alternate layers.
- 72 strips x 30 layers = 2160 channels





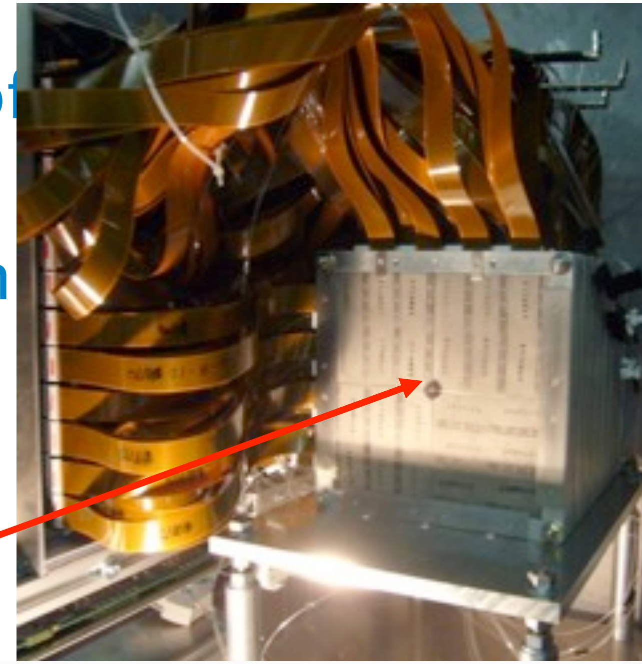


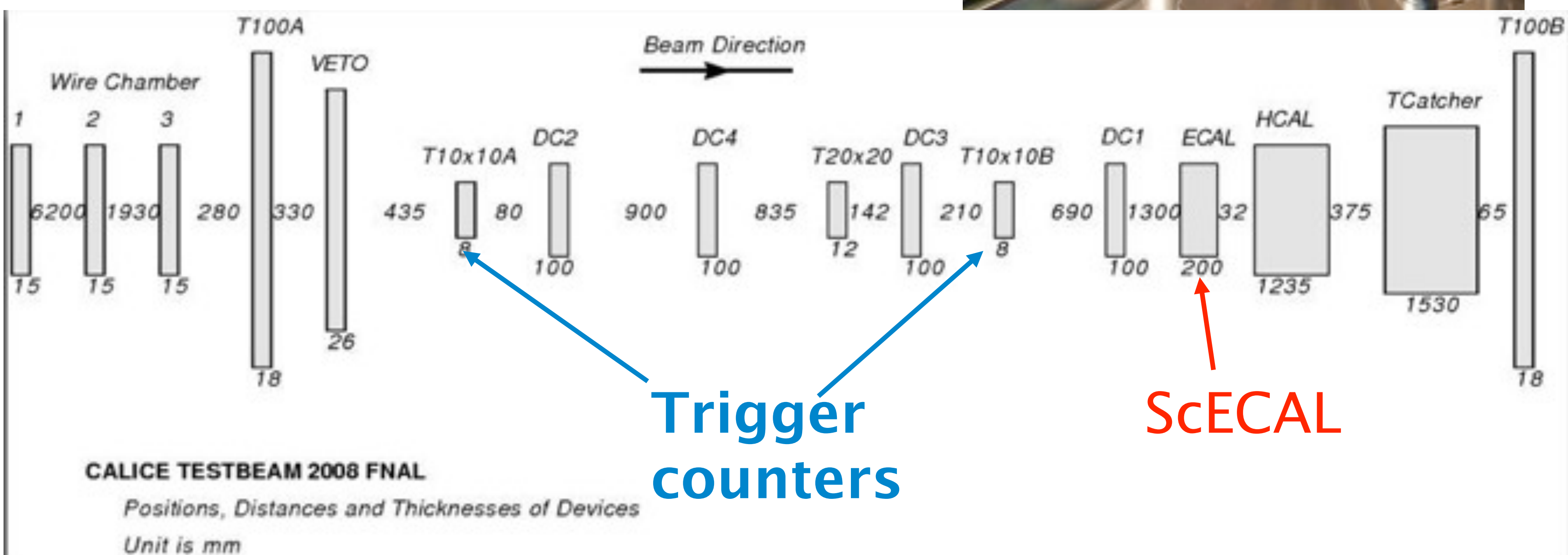


Beam Test in Sep. 2008 & 2009 @ MTBF

Objective : Establish the feasibility of Scintillator-ECAL with 1-32 GeV electron/pion beams.

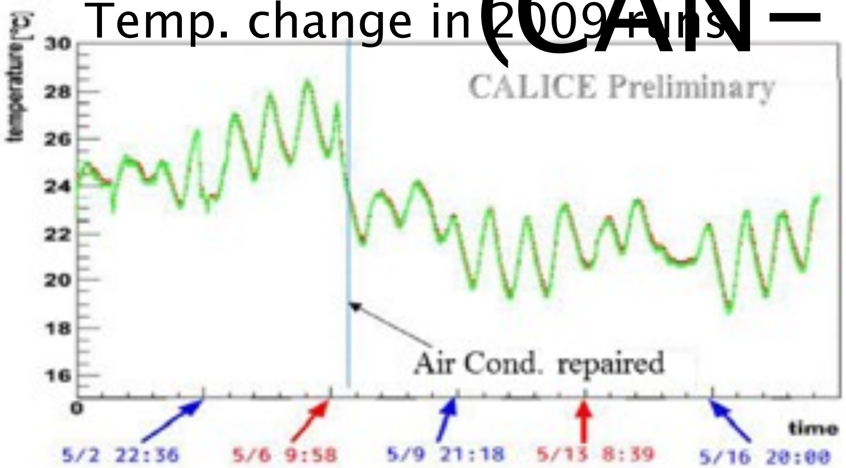
First goal : Evaluate Energy resolution, Linearity for electrons.

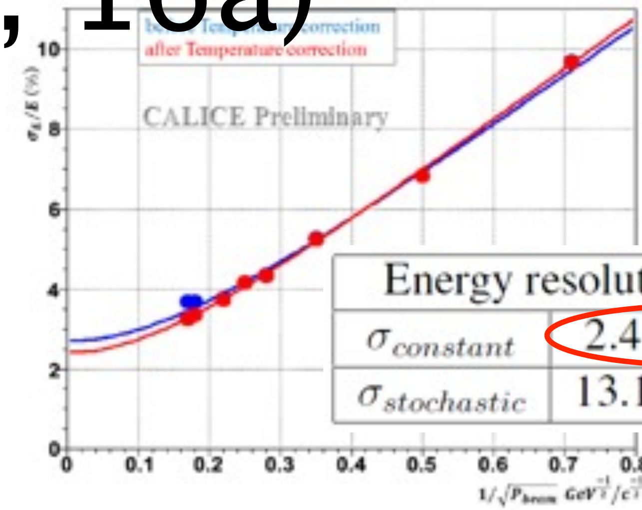




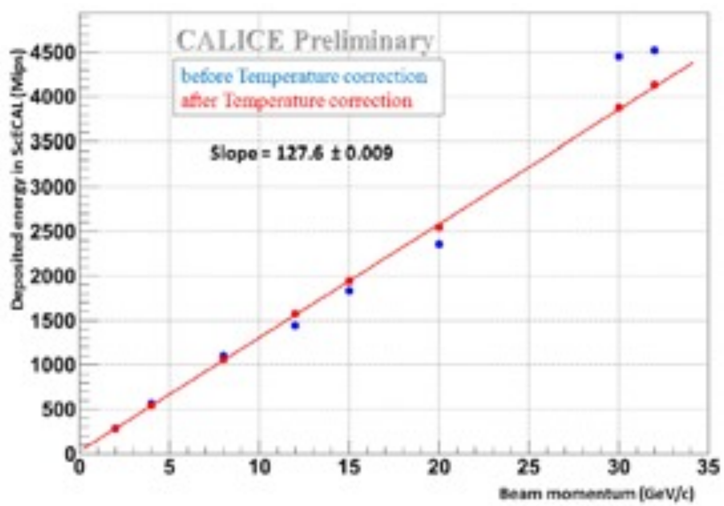
Result shown so far (CAN-16, 16a)

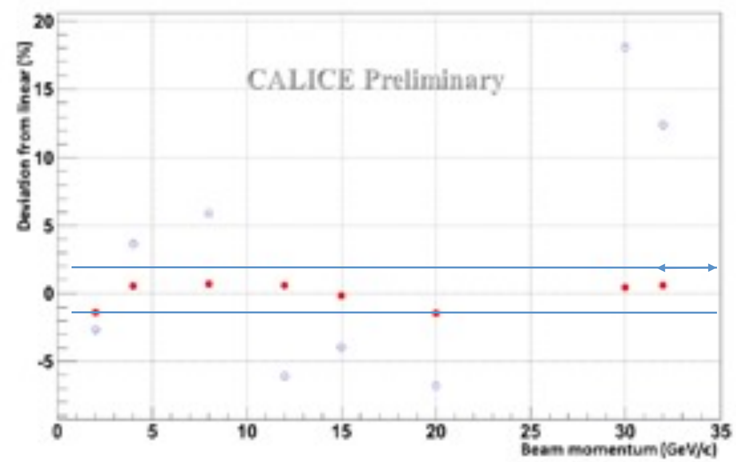
Temp. change in 2009 runs





Energy resolution (%)	
$\sigma_{constant}$	2.41 ± 0.01
$\sigma_{stochastic}$	13.13 ± 0.03





Deviation from linearity
± 1.5%

- Temperature correction to MIP calibration constant significantly improves linearity.
- One unknown point … is ~2.4% constant term reasonable ?

estimation of systematic uncertainties for energy resolution (tentative)

- Systematic uncertainties due to statistical uncertainty of following quantities are estimated by repeating pseudo-experiments.

Source	$\boldsymbol{\sigma_{stoch} \pm \Delta\sigma_{stat} \pm \Delta\sigma_{syst}}$ **(%)**	$\boldsymbol{\sigma_{const} \pm \Delta\sigma_{stat} \pm \Delta\sigma_{syst}}$ **(%)**
Mip calibration	13.03±0.03±0.08	2.42±0.01±0.07
MIP calib. temp. corr	13.03±0.03±0.01	2.42±0.01±0.01
Gain measurement	13.03±0.03±0.01	2.42±0.01±0.01
Electronics Inter-Calib.	13.03±0.03±0.01	2.42±0.01±0.01
MPPC saturation correction	13.03±0.03±0.07	2.42±0.01±0.06
Total	**13.03±0.03±0.12**	**2.42±0.01±0.09**

- No large effect (1~2% on σ_{const} and σ_{stoch}) found in the list above.

2^{nd}–order temperature correction

- Saturation correction & temp. correction procedure

$$N_{\text{fired}}(l,s) = \text{ADC}_{\text{raw}}(l,s)/d_{\text{low-gain}}$$

$$N_{\text{p.e.}}(l,s) = -N_{\text{pix}}^{\text{eff}} \ln\left(1 - \frac{N_{\text{fired}}(l,s)}{N_{\text{pix}}^{\text{eff}}}\right)$$

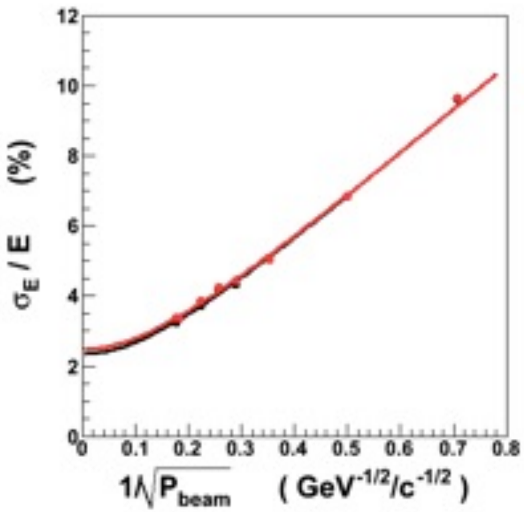
$$\text{ADC}_{\text{corrected}}(l,s) = N_{\text{p.e.}}(l,s) \cdot d_{\text{low-gain}}.$$

2^{nd}–order temp. correction on gain measurement for satur. corr.

$$E(l,s) = \text{ADC}_{\text{corrected}}(l,s)/c(T;l,s)$$

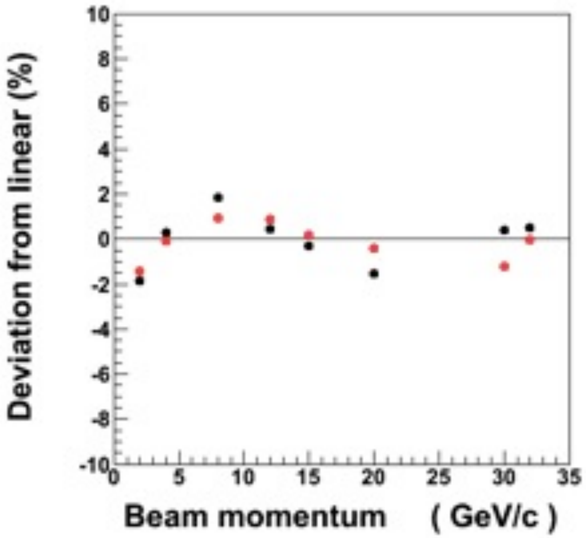
1^{st} order temp. corr for MIP calib. Const.

$$E_{\text{total}} = \sum_{l=1}^{26}\sum_{s=1}^{18} E(l,s)$$



Before/after
2^{nd}–order temp.corr

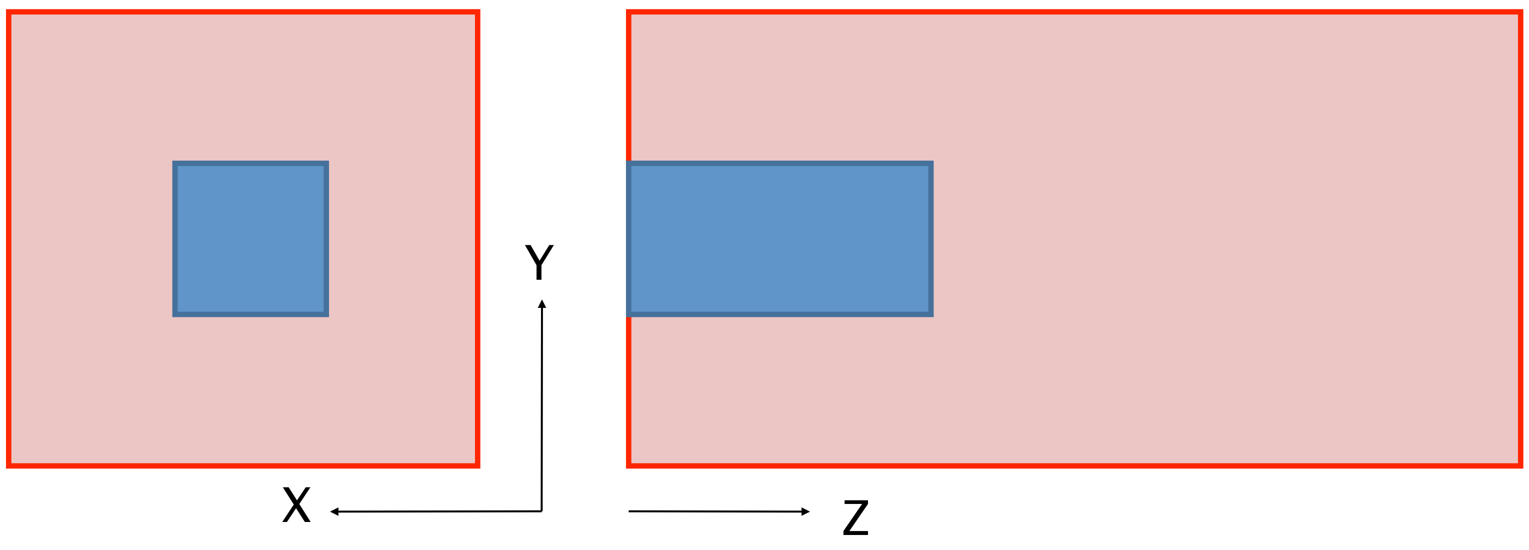
Change of σ_{const} ~ 0.1%.



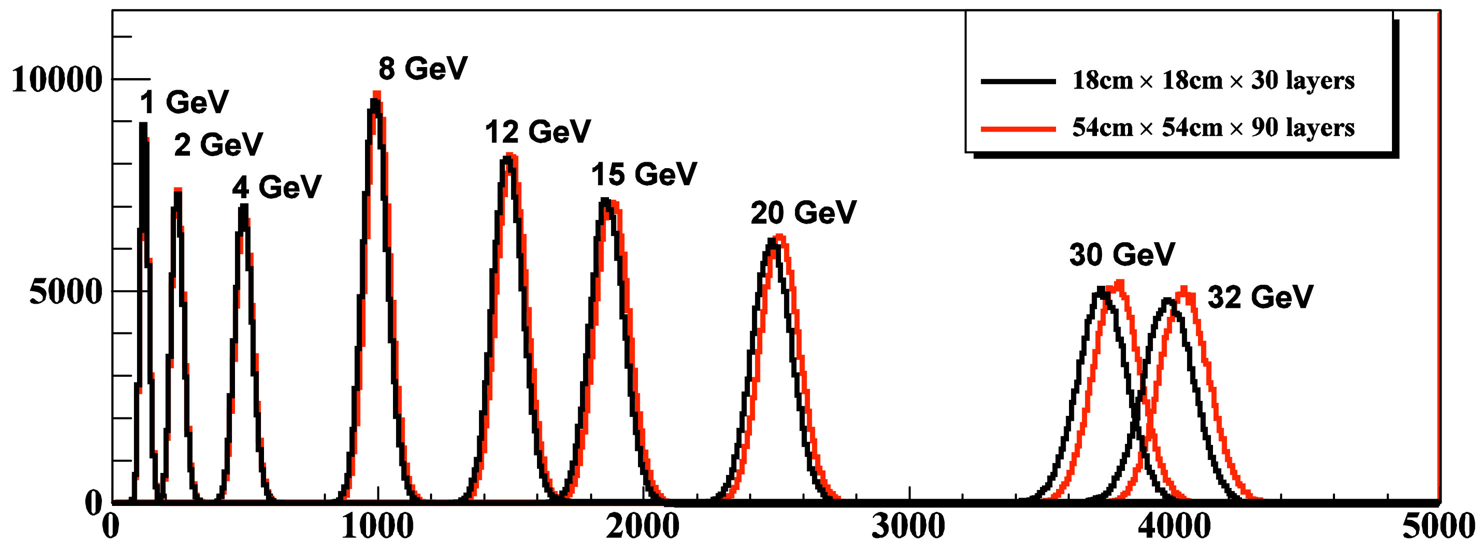
- Only very small effect observed.
- Can not be a source of 2.4% constant term.

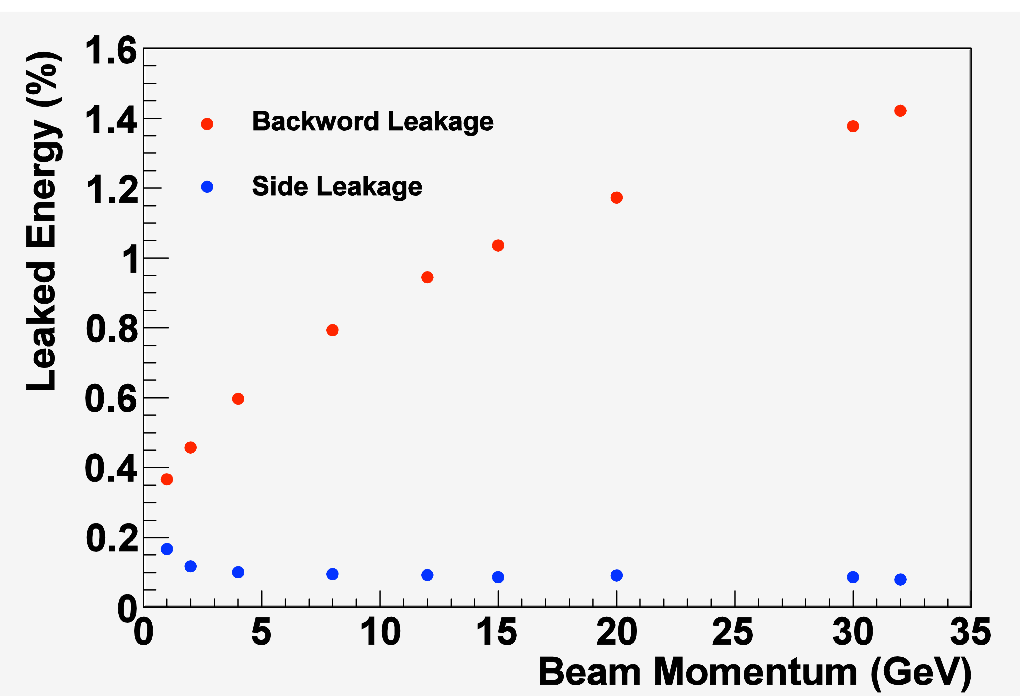
Mokka simulation of the ScECAL prototype for shower-leak estimation

- Mokka simulation for ScECAL prototype is being developed.
- To estimate shower leakage, ScECAL prototype with standard-size ($18x18cm^2$ x 30 layers) and large-size ($54x54cm^2$ x 90 layers) are simulated.



Estimation of EM shower leak by Mokka





Mokka simulation tells :

- There are 0.2 – 1.5% lateral leaks with 1–32 GeV electron beams,
- Lateral leak is small (~0.1%),
- The lateral leak affects to const term of energy resolution for **0.7 $\pm$ 0.1 %**, which still doesn't explain σ_{const}~2%.

Effect of beam momentum spread

- FNAL beams division told that spread of beam momentum at MT6 would be :
  - 1–3% from beam optics
  - There is an actual measurement only on 1–8 GeV using lead-glass calorimeter,

    (2.7±0.4)% for 1– 4 GeV, (2.3±0.3)% for 8 GeV beams
- Another constraint could come from size of trigger counters (10x10 cm^2).
- σ/E of ScECAL ~ 3.5% @ 32 GeV, therefore 1–3% of momentum spread would give non-negligible effect to constant term.
- An issue – can we simply take "1–3% by beam optics" for $p_{beam}>8$ GeV ?

Effect of beam momentum sprea

Assumption 1 :

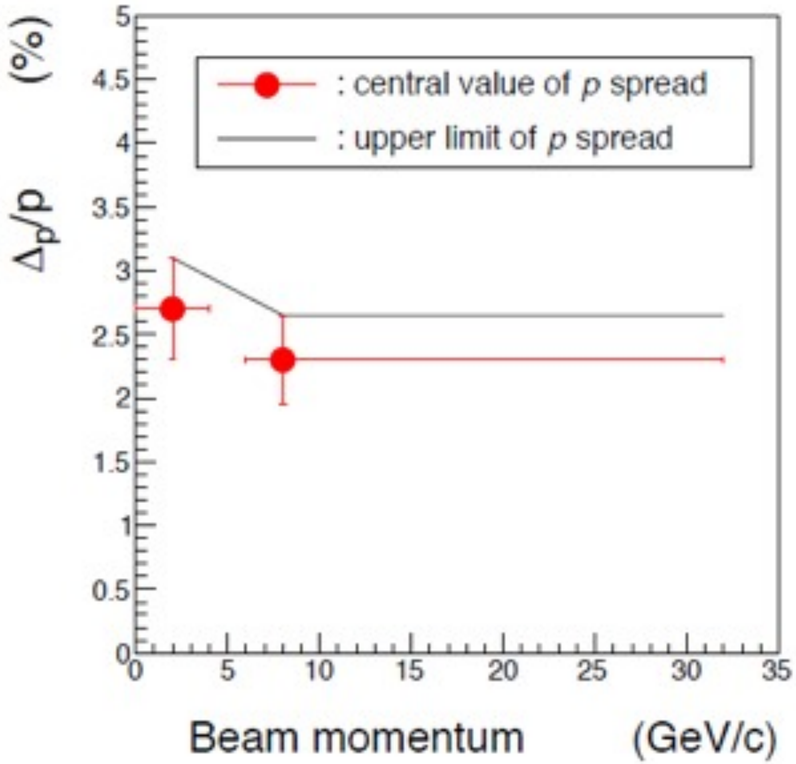
- For p_{beam}<=8GeV, there are measured values of $\Delta p/p$.
- For p_{beam}>8GeV, just take value of $\Delta p/p$ measured at 8GeV

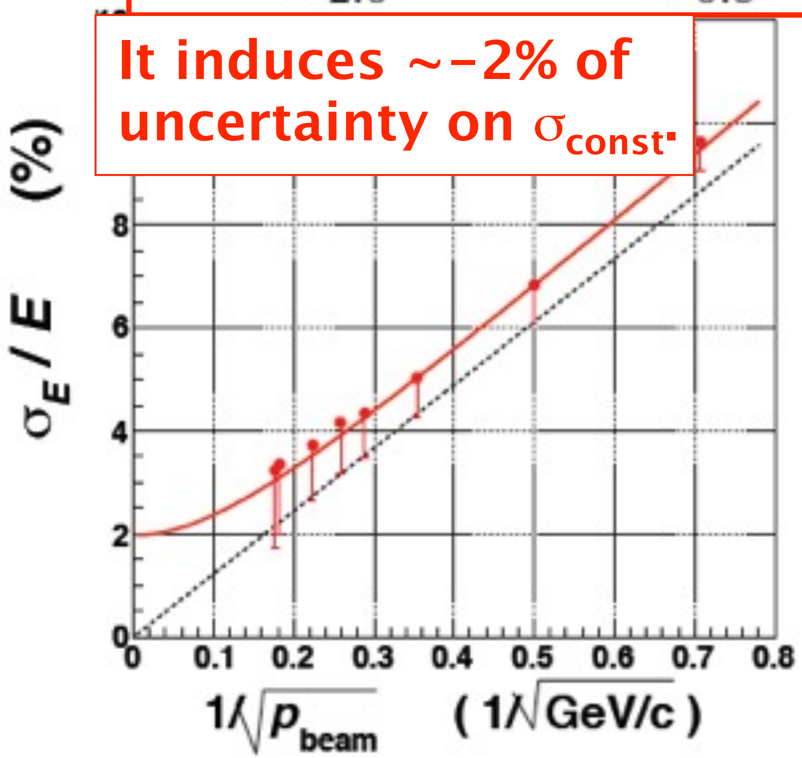
In principle momentum spread should be smaller in higher energy

with less effect of multiple scattering.

constant term	stochastic term
$2.0^{+0.1}_{-2.0}$ (%)	$13.1^{+0.1}_{-0.8}$ (%)

It induces ~−2% of uncertainty on σ_{const}.

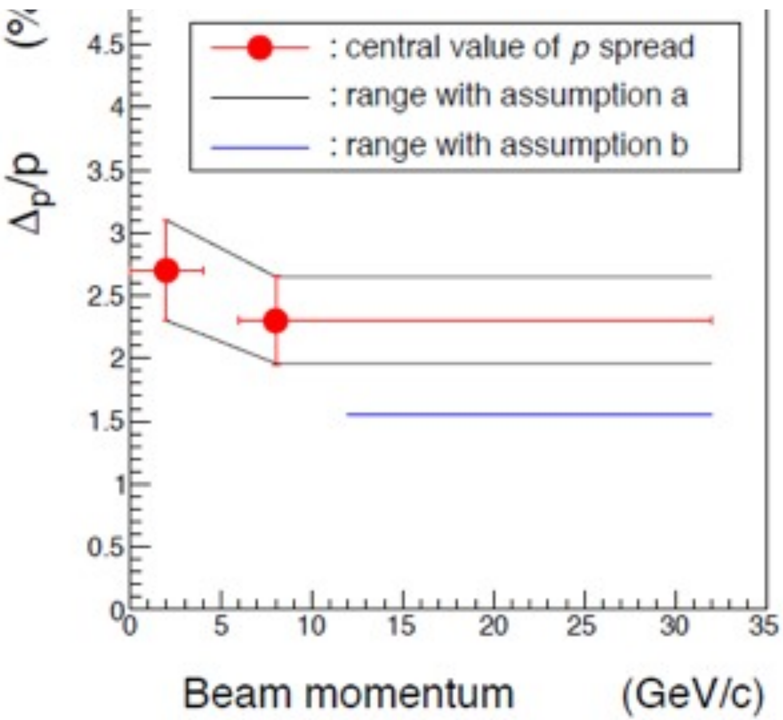




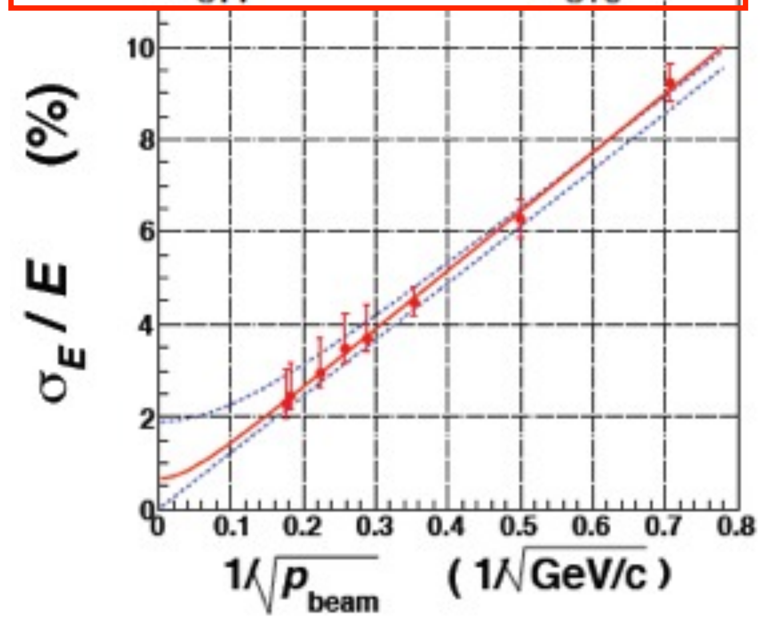
Effect of beam momentum spread

Assumption 2:

- For p_{beam}>8GeV, assume beam momentum spread as :
  - Upper bound of $\Delta p/p$ is taken from 8 GeV
  - Lower bound of $\Delta p/p$ = 1.5% considering beam optics and effect of multiple scattering.
- With those assumptions, $\Delta p/p$ is subtracted from σ/E at each p_{beam}.



constant term	stochastic term
0.7 $^{+1.2}_{-0.7}$ (%)	12.8 $^{+0.5}_{-0.6}$ (%)



Summary

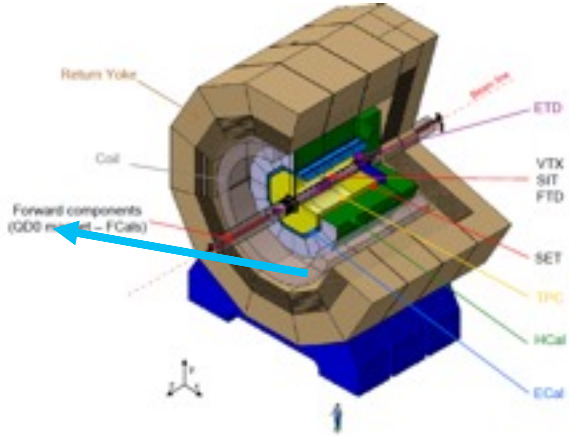
- Analysis of the ScECAL beam test @ FNAL is ongoing toward publication.
- Obtained results, especially non-zero constant term, are found to be reasonable considering :
  - Systematic uncertainties
  - EM shower leak
  - Beam momentum spread (in extent of available info)
- Is the beam momentum spread information convincing enough?

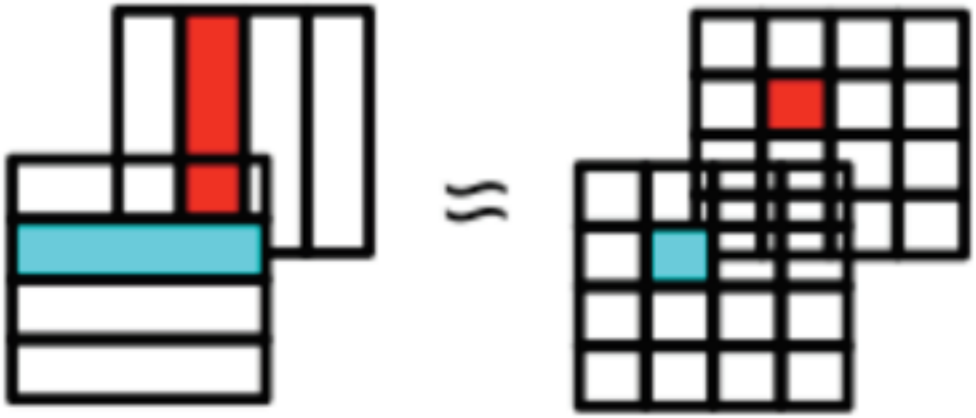
  Will query to FNAL beams division if more precise information available.
- Tuning of Mokka simulation for ScECAL prototype underway.
- Further analyses are expected (man-power wanted!)
  - Pion data analysis combining ScECAL & AHCAL
  - π^0 run analysis

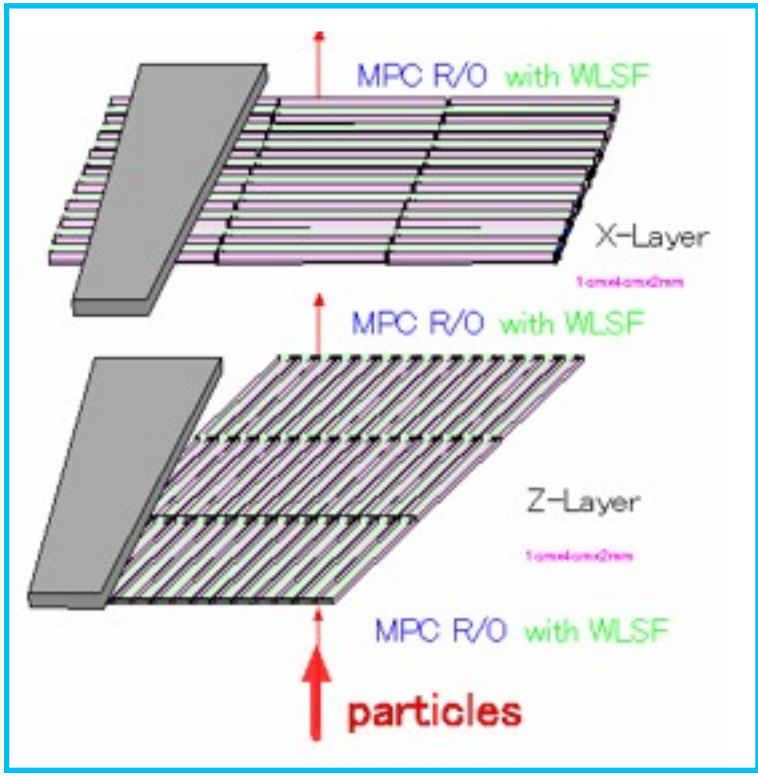
Backups

he Scintillator-Strip Electromagnetic Calorimet

- Sampling calorimeter with Tungsten-scintillator sandwich structure.
- Scintillator-strip technology adopted to achieve fine granularity.
- Lateral Segmentation : 1 ~ 0.5 cm
- Huge Number of channels (~10M channels).
- Need to establish sufficient performance while keeping the low production cost.
- **First need to establish the**



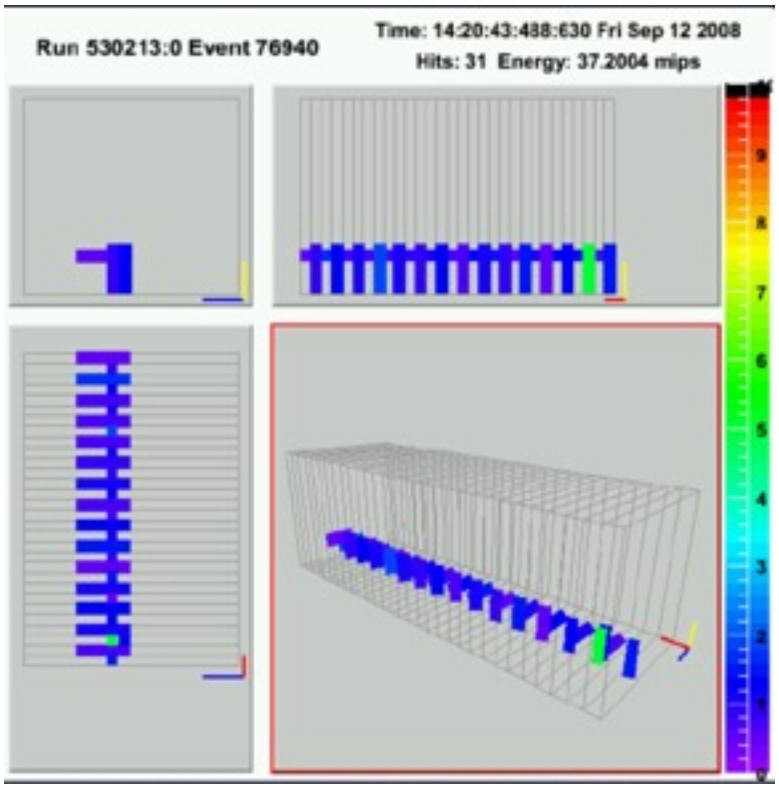




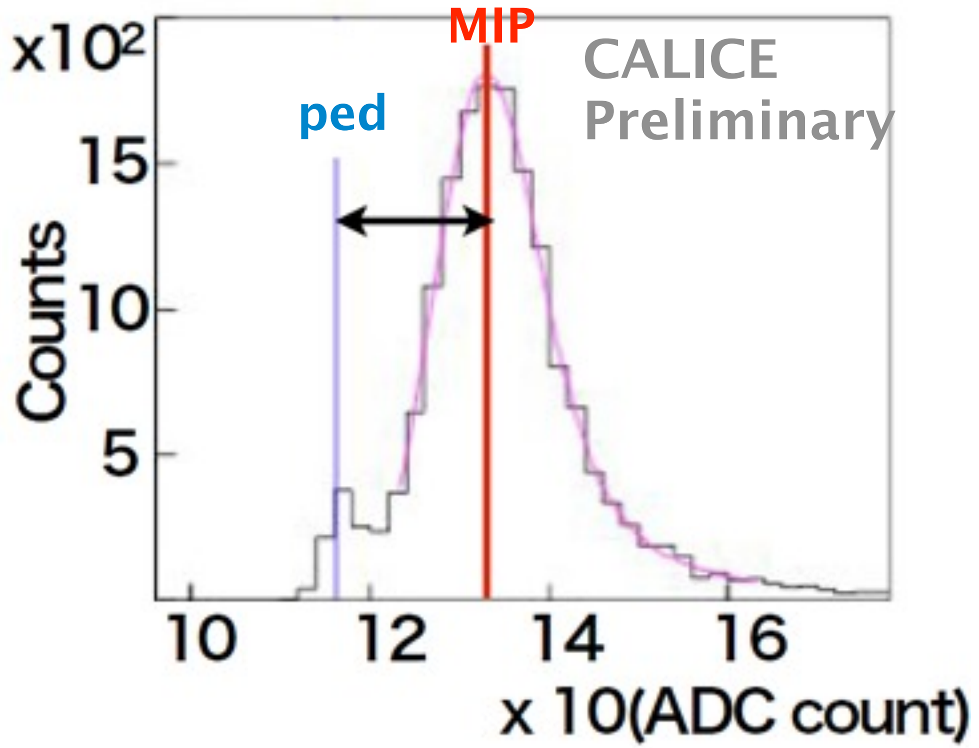
Strip-by-strip response calibration with muons

The scintillator strip response calibration has been done using
Minimum Ionizing Particle (MIP) signal by muon beams.

A typical muon event passing the ScECAL



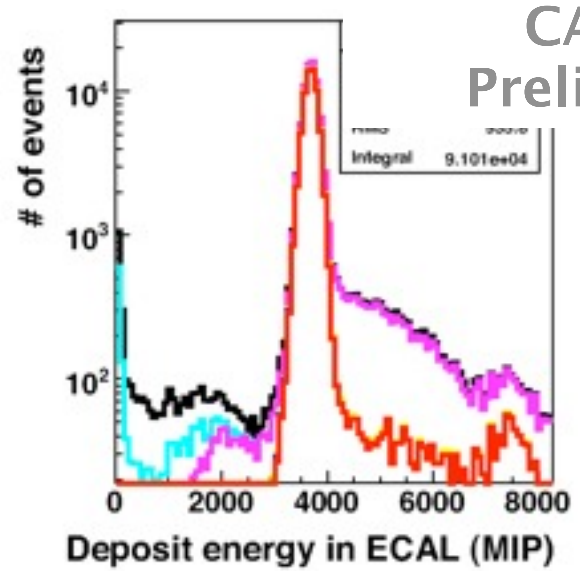
MIP equivalent signal on one strip

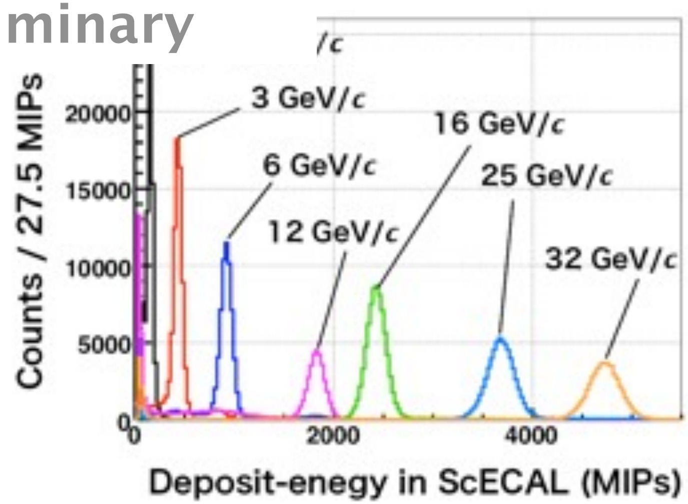


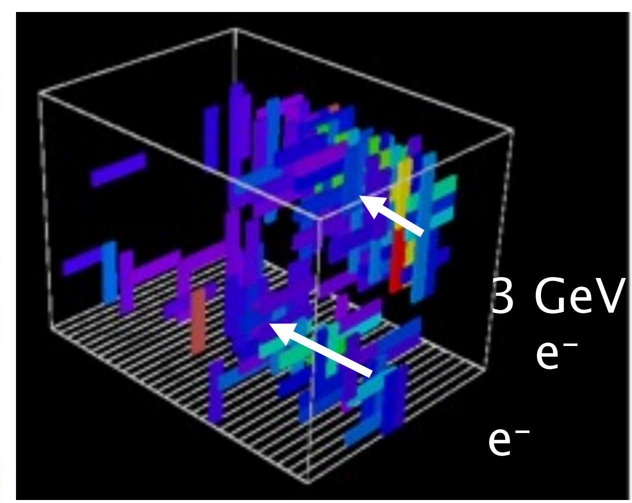
Uncertainty of the response calibration < 1% (statistical error

Electron event selection

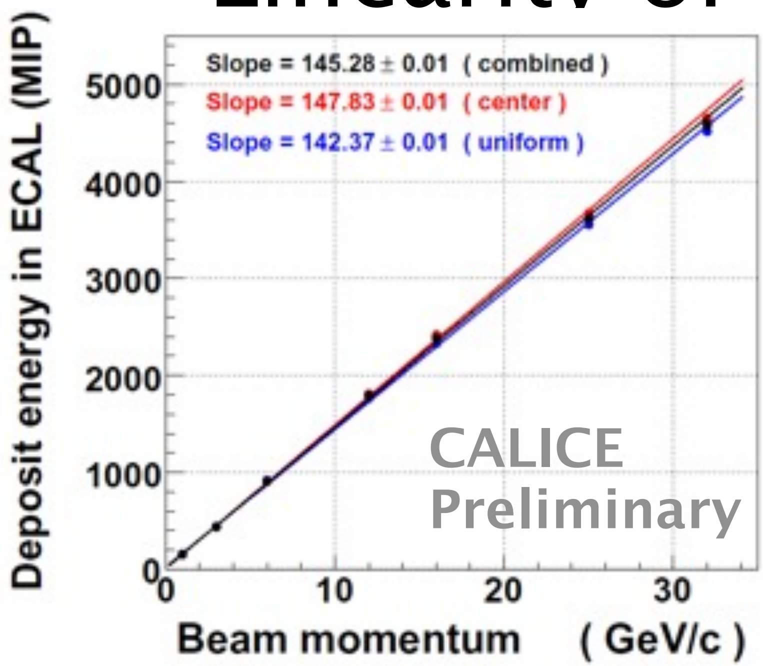
- The first task is evaluate the ScECAL performance for electr
- The beam is mixture of e^- / π^- / μ^- components.
- Cerenkov counter signals have been used for the electron tr however still offline event selection is necessary to purify th electron sample.
- Event selection is done based on :
  - Longitudinal / lateral shower shape
  - π^- / μ^- veto by the HCAL signal located at downstream

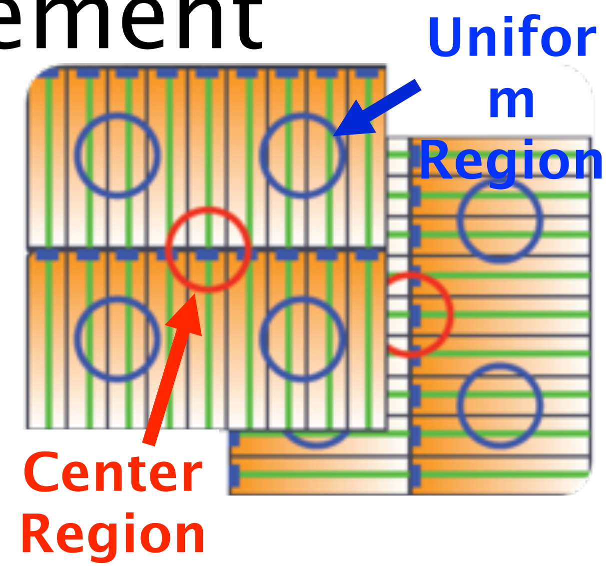


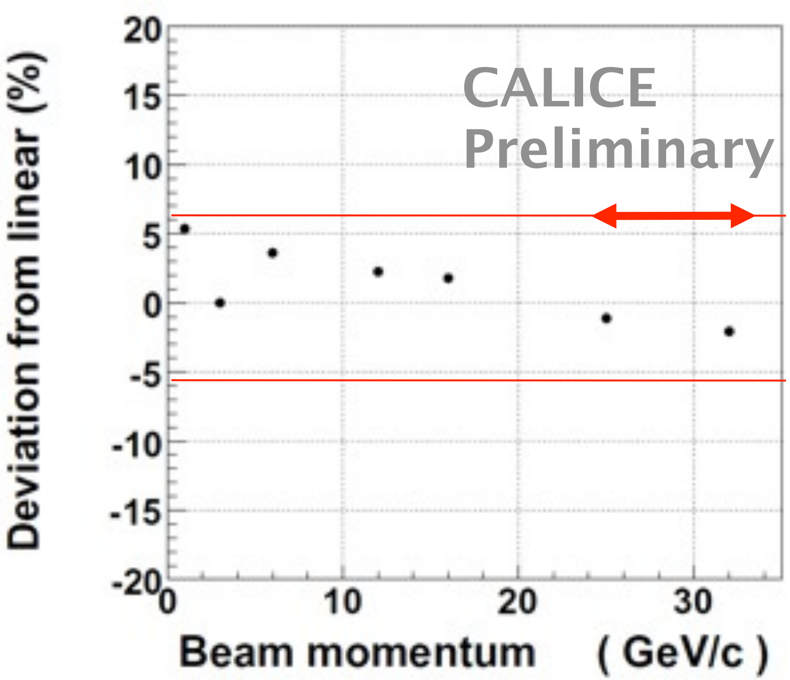




Linearitv of the electron energy
asurement

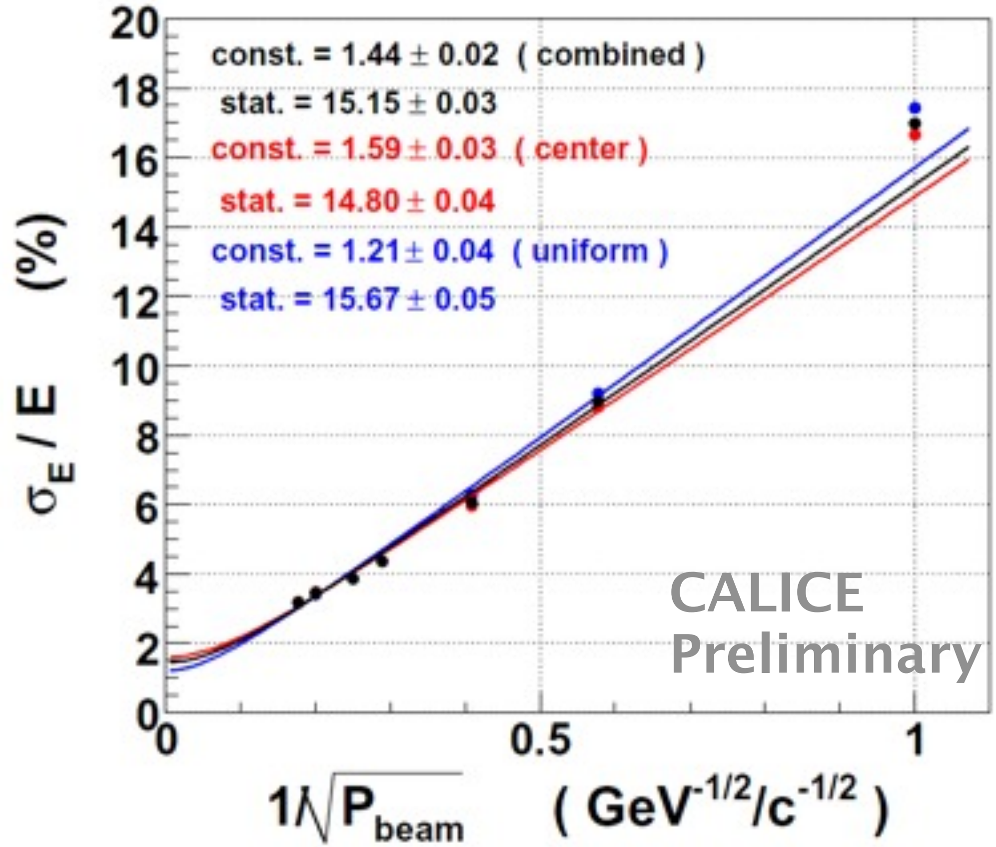


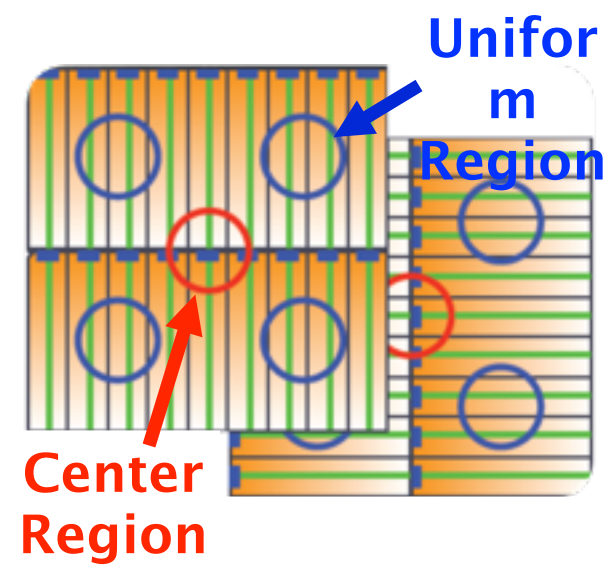




- Reasonably uniform response over the entire detector region.
- ~±6 % of non-linearity in 1-32 GeV energy region, needs to be improved.
- Reason under investigation, possibly due to:
  - contamination of e^- data by π^-/μ^-
  - Lateral and longitudinal shower leakage

Energy Resolution for electrons



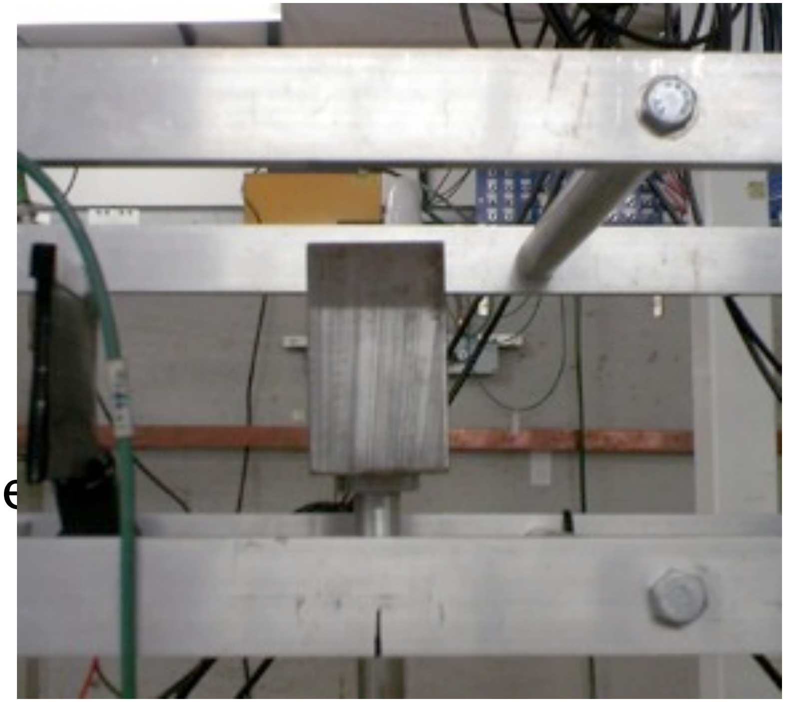


$$\frac{\sigma}{E} = \frac{(15.15 \pm 0.03)\%}{\sqrt{E}} \oplus (1.44 \pm 0.02)\%$$ (preliminary, errors are stat only)

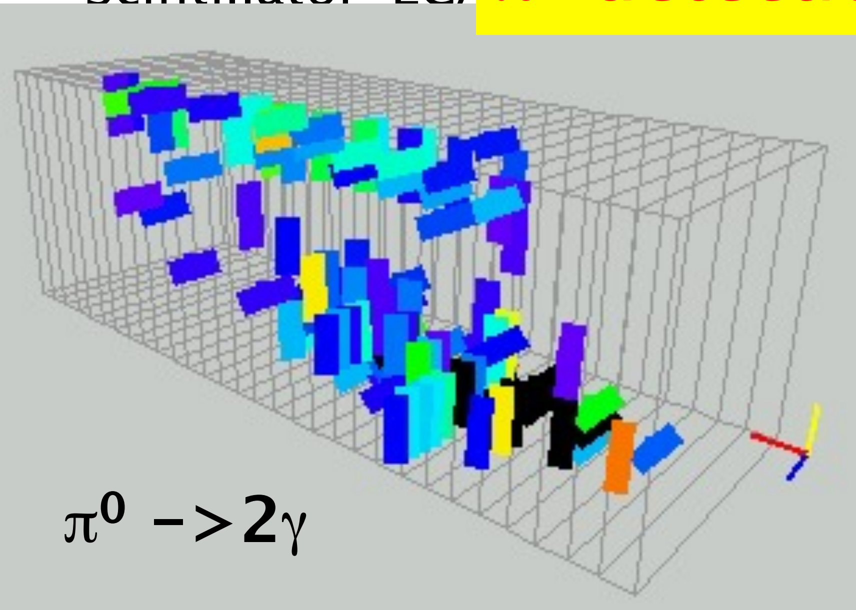
- Observed constant term rather large, investigation underway.
- Also due to the shower leakage or the gain variation of photo-sensor?

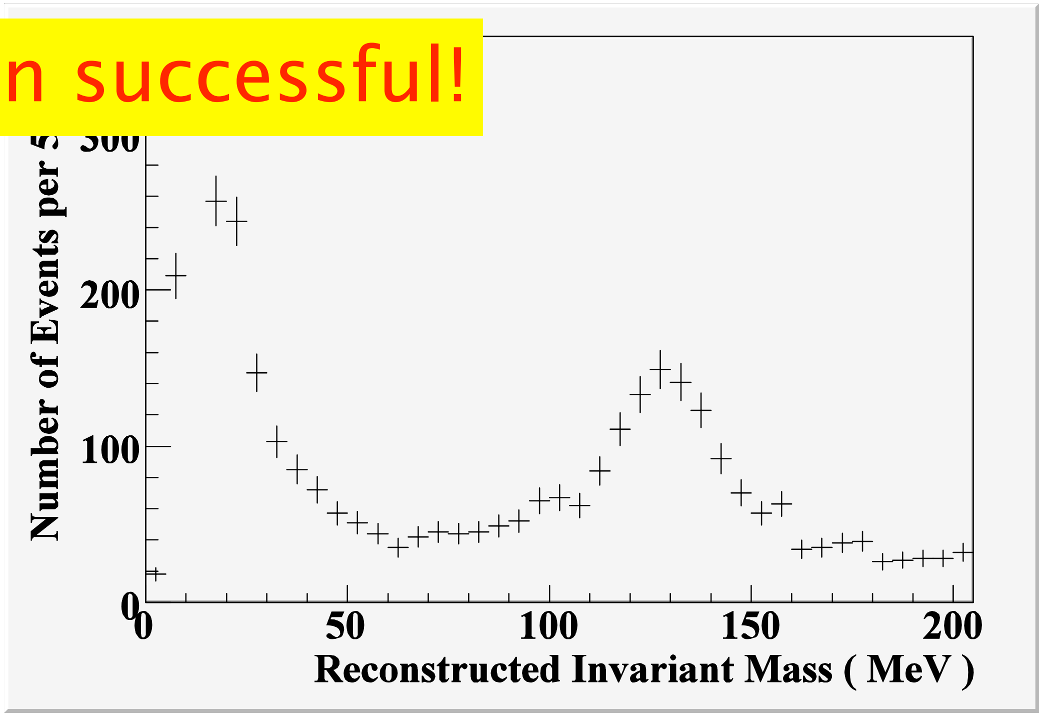
π^0 runs
(very preliminary)

- Ability of π^0 reconstruction from 2γ might be useful to improve jet energy resolution.
- Generate π^0 by putting iron on beamline and injecting 16-32 GeV π^- beam.
- Try reconstruction of the generated π^0 with Scintillator-ECA

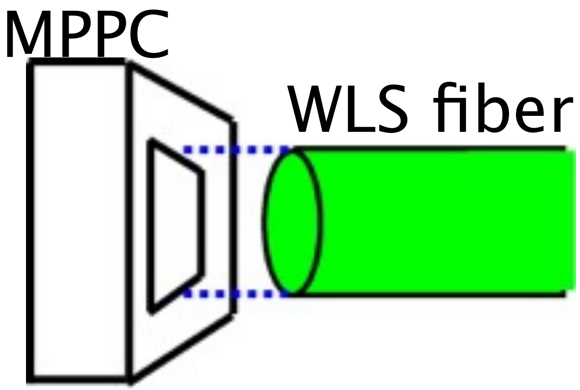


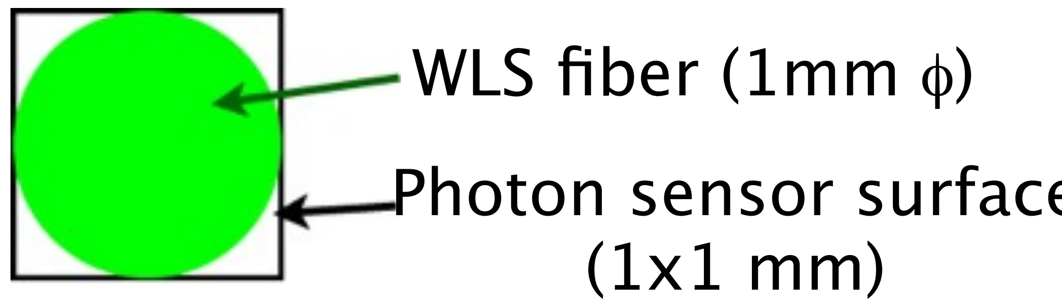
π^0 detection successful!



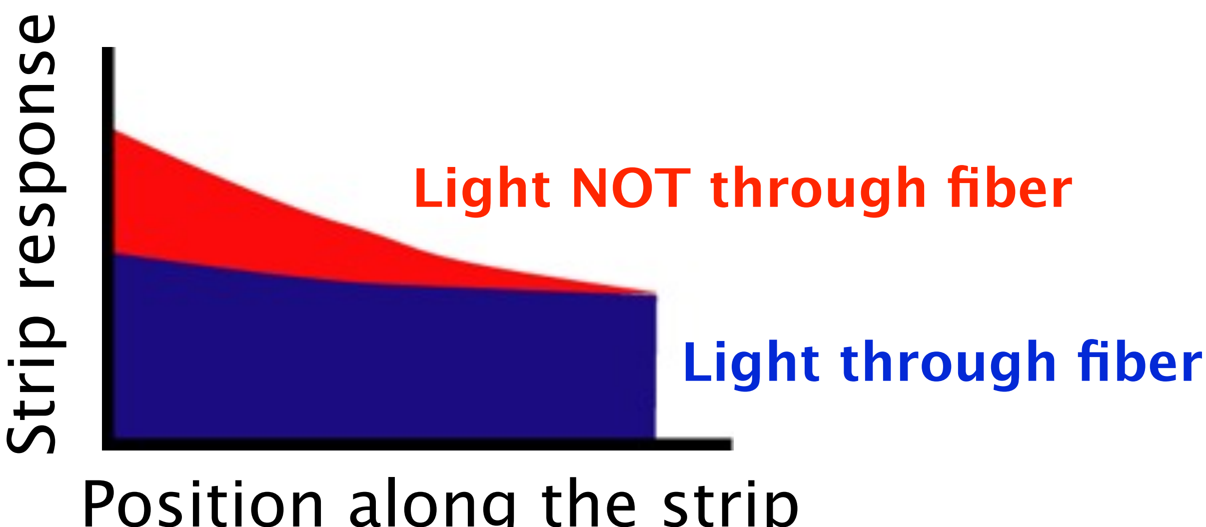


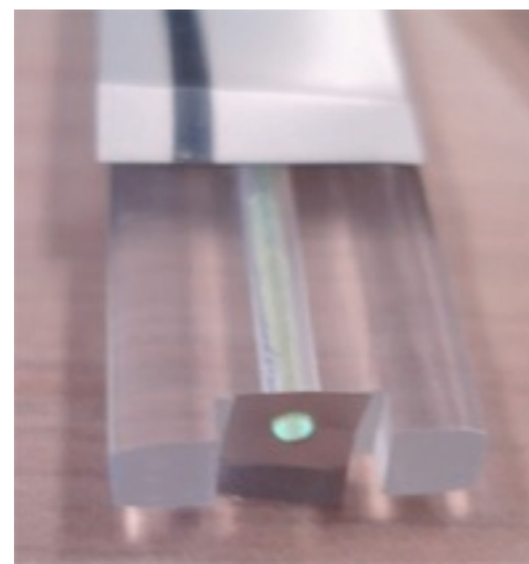
Further Improvement of the strip response uniformity



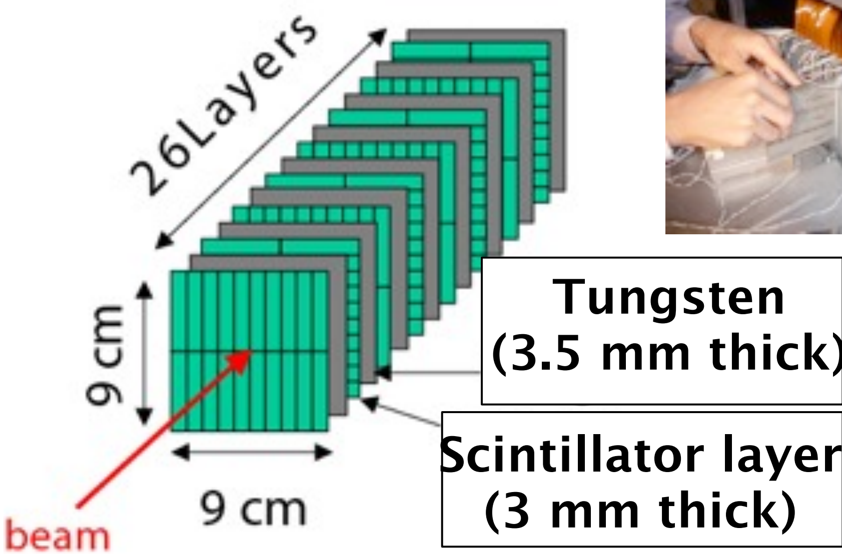


- Light through WLS fiber … uniform
- Light **NOT** through the fiber … not uniform
- Shading the “direct” light improves the non-uniformity.

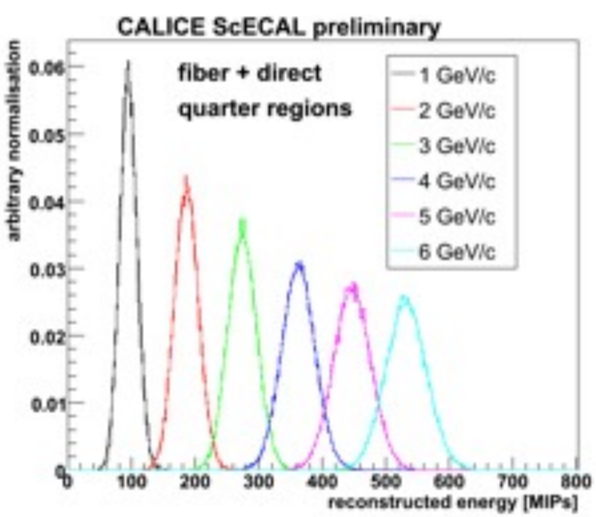


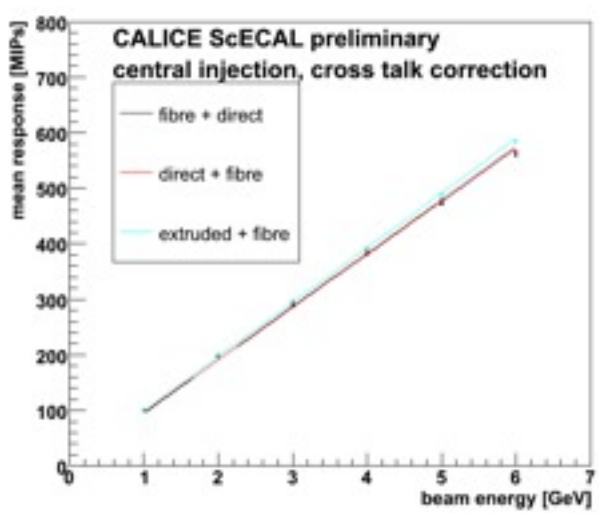


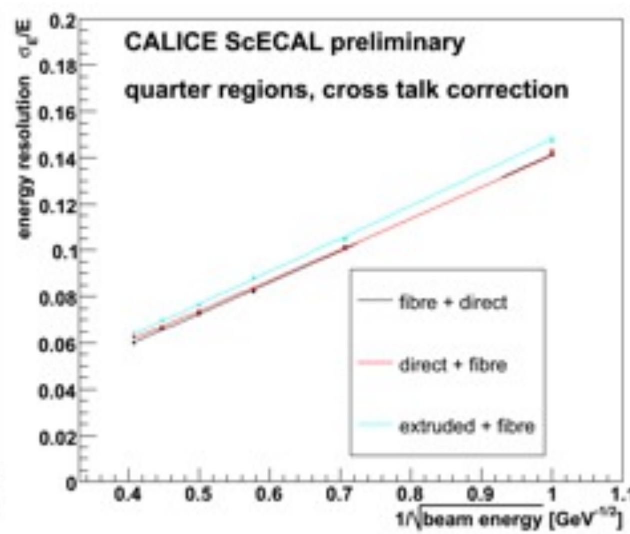
1st small prototype performance (tested in 2007 at DESY, 1–6 GeV e^+)



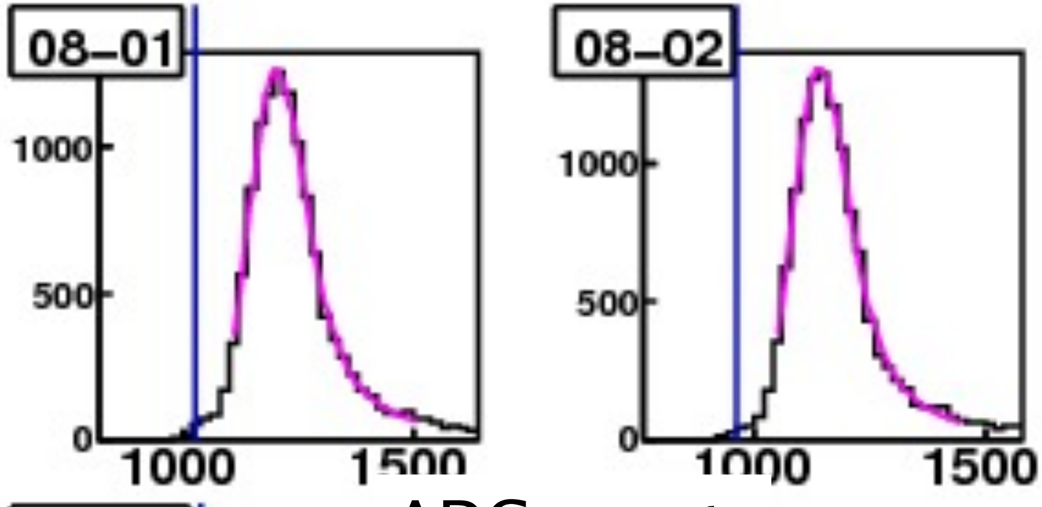
- The 1st prototype tested at DESY electron synchrotr
- Results show sufficient feasibility in 1–6 GeV e^+ en





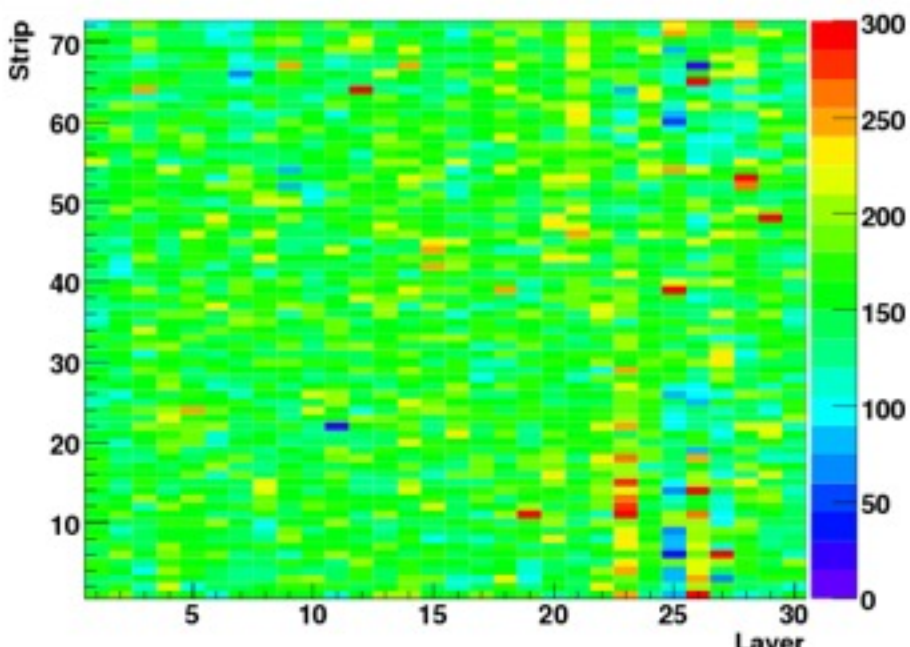


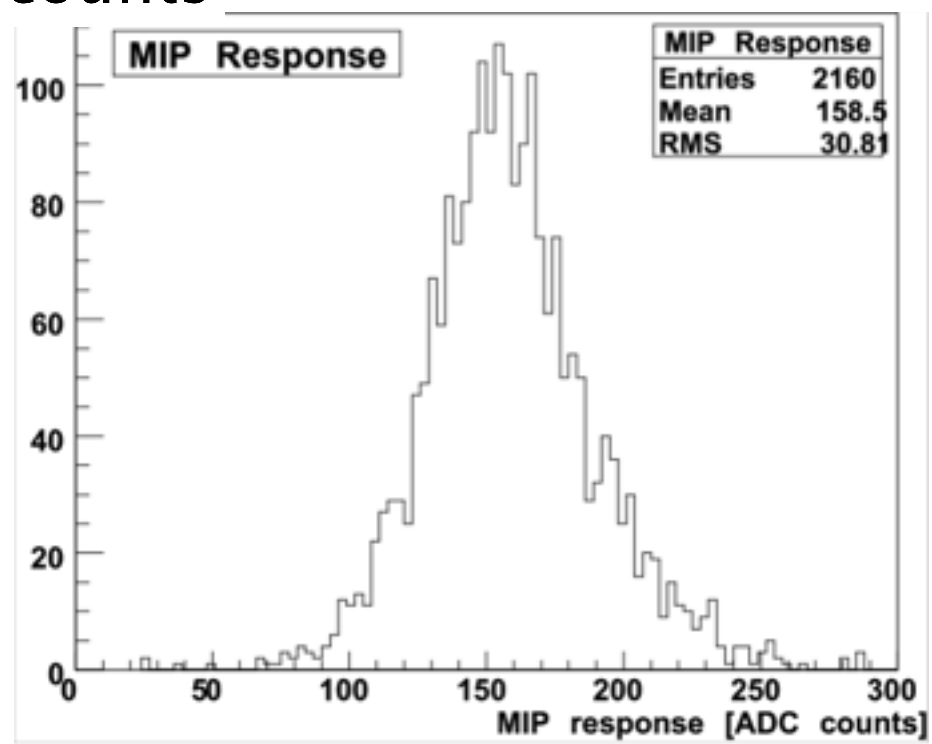
Muon MIP signal (preliminary)



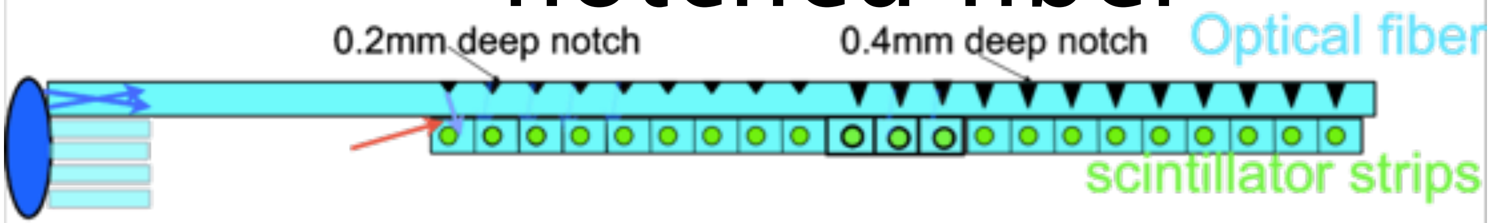
ADC counts

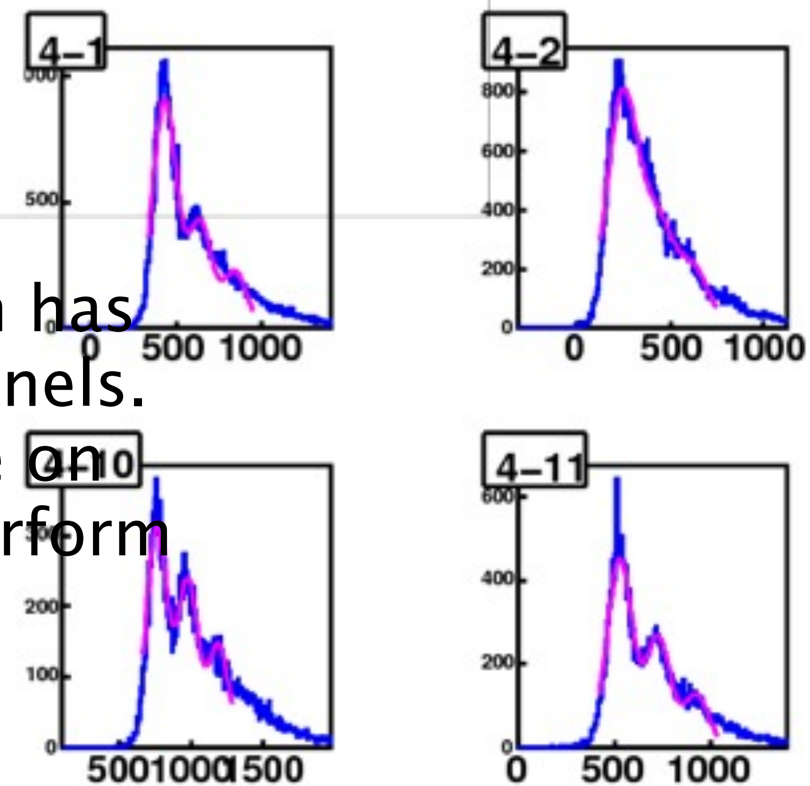
MIP response map





Gain monitoring by LED and notched fiber





Nice pedestal-1pe peak separation has been observed on ~70% of all channels.
For other channels, electrical noise on readout board was too large to perform the gain measurement.
Investigation is underway.